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SMALL PIPE HYDRONIC SYSTEM

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PREFACE

The following is intended as a report of the pipe sizing procedures used in designing the small-pipe, hot-water system tested in the Research Home during the winter of 1958-59. It also contains a description of installation procedures and a discussion of test results. This report neither replaces nor obsoletes present I=B=R Installation Guides, but rather it should suppliment them. There is no change in the method of calculating heating loads, as given in I=B=R Installation Guide H-20, nor in the methods of selecting the heat distributing units, boiler size, air cushion tank size and pump as directed in I=B=R Installation Guide 500.

The pipe sizing tables in Guide No. 500 limit the minimum pipe size in the main to 3/4 in. and in branches to 1/2 in. In many instances these are larger than required. In the design of the small pipe system these pipe size limitations were disregarded.

Introduction

The broad objectives of the research program conducted at the University of Illinois for the Institute of Boiler and Radiator Manufacturers are to find ways to further improve performance of hydronic systems and to reduce the operating and installation costs. The heating project for the winter of 1958-59 was aimed at reductions in the cost of installation.

Today quiet pumps are available which will operate at heads of more than 10 ft. of water. The system installed in the I=B=R Research Home during the summer of 1958 was designed to take full advantage of the high head of the modern pump. Furthermore, soft copper tube was used throughout. This is readily bent, eliminating the need of many fittings required in systems installed in more conventional ways. These practices resulted in a reduction of about $150.00 in the cost of installing the piping system for a one-pipe, hot-water system in a two-story, six-room house having a calculated heat loss of 43,300 Btuh at 70 F indoors and -10 F outdoors.

System Design

The operating conditions for which the system was designed were as follows:

Average water temperature	215 F
Temperature drop through the system	20 F
Temperature drop through each room heating unit	20 F
Total water circulation rate	4.3 GPM
Pump head at above flow rate	14 Ft. of water

Figure 1 is a schematic diagram of the system with the design water flow rates for each section of piping indicated. This system was designed by adding the equivalent length of the fittings to the measured length of the piping to determine the equivalent length of the pipe. Knowing the rate of water circulation through each section of the piping and the pressure head available, it was possible to make a suitable selection of copper tube sizes from a standard friction pressure loss chart. It was necessary to extrapolate the chart down to nominal 1/4 in. tube as no chart could be found containing tube sizes smaller than 3/8 in.

A preliminary study indicated that pipe sizes for this system would be too small to permit the use of present makes of one-pipe fittings. Therefore, the fitting illustrated in Fig. 2 was improvised. The diameter of the orifice was such that the resistance to water flow through the orifice was equal to the resistance offered by 12 ft. of straight tube of the same diameter as the main. In selecting the pipe sizes for the main, the length of main was taken as the measured length plus 12 ft. for each orifice in the circuit. Since the resistance offered by the return tee was equivalent to about 2 ft. of tube and at least 1 ft. of tube was located between the supply and return tee, the head available to circulate water through the

Pushing riser through stud space to basement. When end of tube reaches basement second man pulls the end free of the sill and pulls enough into the basement to make connection to the main. Man above then cuts riser from coil, leaving enough tube to make connection to the heating unit.

Top end of riser is cleaned and soldered into adaptor in the end of the heating unit.

branch circuits was assumed to be equal to the total friction head in 15 ft. of the main. Pipe sizing calculations are summarized in Table A.

Nominal 3/4 in. type L copper tube was required in the trunk main. The branch mains consisted of nominal 1/2 in. tube while the radiator runouts and risers were either 3/8 in. or 1/4 in. tube, depending on the capacity of the room heating unit and the length of the piping connections. Sweat fittings were used throughout the system.

While the tube used in this system was smaller than that ordinarily used, it should be pointed out that, at the design water flow rate of 4.3 Gpm, the maximum water velocity in the system would be 3 ft. per sec. This velocity is low enough that there would be no danger of noise resulting from the water flow.

Table B shows the estimated installation costs for both a conventional one-pipe and the small pipe heating system for a new six-room, two-story house similar to the I=B=R Research Home. Estimated installation time was based on experience gained from the installation of such systems in the Research Home. The total cost of materials in the conventional iron-pipe system was $104.25 as compared to $87.73 for the small pipe system. Labor costs for the conventional, and the small pipe systems were $220.50 and $84.00 respectively. These estimates cover only the costs of pipe, fittings, and the time required to install the piping system. They do not include the cost of the boiler and radiation nor the time required to install these items except for connecting the piping system to them. The total cost of installing the piping system for the small pipe system was approximately $150.00 less than the installation cost of the more conventional piping system.

Installation Procedure

The real advantage of using small diameter, soft copper tubing for the piping system was in the ease and speed of installation. The following procedure was followed in installing the experimental system in the I=B=R Research Home. The radiation in this system consisted of cast iron baseboard. Undoubtedly a detailed study of installation procedures could result in some further short cuts, but even so, the procedure listed below resulted in a saving of about 40 man hours as compared to that required to install the same system using the larger size of iron pipe usually employed in systems such as this one.

Step 1. Assemble baseboard heating units and locate in rooms where they are to be installed.
Two men required.

Step 2. Cut necessary holes for risers.
One man required.

Step 3. Rough in risers.
Two men required. Risers to second story units were pushed down through the stud spaces in the walls from the room to the basement. Risers for first story units were run through floor to basement. Sufficient tube was left on both basement and room ends of the risers to make connections to the main and the baseboard. Prior to pushing the tube through the stud space, the end of the tube was crimped with a pair of pliars to prevent insulation or dirt from entering the tube.

After both risers are soldered into the adaptors at the ends of the heating unit, the unit is pushed back into place along the wall. Surplus riser slips through stud space to basement.

After installation of room heating units is completed the basement ends of the risers are cut to length and soldered into the tees in the main. As the connection to the tee is completed, the main is fastened into place following the chalk line indicating its proper location.

Step 4. Connect risers to room heating units.
One man required. The baseboard unit was laid on the floor just in front of the wall along which it was to be located and iron to copper adaptors were screwed into the ends. Following this the unit was placed in an upright position a few inches from the wall. Fireproof insulating board was placed under the end of the unit to protect the floor. The end of the riser was cut and cleaned and sweat into the fitting at the end of the heating unit.

Step 5. Locate unit against wall.
Two men required. After soldering the risers to the heating unit, the heating unit was pushed back into place along the wall. The extra length of the riser required to reach the heating unit when in position for sweating was pushed back into the stud space for second story units and through the floor into the basement for first story units.

Step 6. Indicate position of basement heating main by chalk line across the bottom of the studs.
Two men required.

Step 7. Connect main to the boiler.
One man required. Work can start at either the supply or return connection to the boiler. If two men are working, one can start at the boiler supply and the other at the return.

Step 8. Run mains.
One man required. One end of tubing was cleaned and sweat to the fitting at the boiler supply. Tubing was bent as required to follow the position indicated by the chalk line. Tube was fastened to bottom of joists with staples or straps as work progressed. Fasteners were located about 3 ft. apart and care was taken to see that they were not tight on the tube. This permitted freedom of movement without causing expansion and contraction noises. Tubing was cut to length where tees were required and fittings were sweat into place before the tube was fastened to the bottom of the joists. The bottom end of radiator risers were cut to length and soldered to the main in turn. The orifice was inserted in all supply tees in the position indicated in Fig. 2. The tubing held the washer in place.

If two men were working, they started at opposite ends of the main and worked toward each other. (If there are two or more circuits, they may work on separate circuits.)

Performance of small pipe system

Performance of the small pipe system was observed in the I=B=R Research Home throughout the winter of 1958-59. This was one of the most severe winters in Urbana, Illinois, in recent years. Minimum temperatures were as low as -9 F and these were accompanied by average wind speeds of about 10 miles per hour with gusts up to about 30 miles per hour. All through the winter the operation of the small pipe system was satisfactory in all

respects. No difficulty was experienced in maintaining the desired room air temperatures even during the coldest and most incliment weather. Floor to ceiling air temperature differences were the same as those obtained in previous years when testing baseboard heating systems having conventional one-pipe piping systems.

Because of restrictions on the use of gas, it was necessary to use oil as the fuel during the tests on the small pipe system. No other baseboard heating system has ever been tested in the Research Home using fuel oil; however, the oil consumption obtained with the small pipe system in 1958-59 compared favorably with that obtained with the first heating systems ever installed in the Research Home. These early systems were oil fired and used small tube radiators.

According to the design assumptions the rate of water circulation through the trunk main should have been 4.3 Gpm. By actual measurement it was found to be about 5.8 Gpm. No actual measurement was made of the pump head developed. The high measured water flow rate indicated that either the pump head was well above the catalogued value or else the total resistance of the piping system was less than assumed. It is probable that the latter was the principal factor for the following reasons: (1) a large section of the return trunk of the small pipe system was not changed from the 1 inch iron pipe used in previous systems. This was left in as it contained the flow measuring station. (2) the required water flow rate in some sections of the piping was less than the maximum carrying capacity and (3) in estimating the pipe resistance no allowance was made for the fact that the actual flow rate through the parts of the main located between each pair of risers was at a reduced rate due to diversion of part of the water through the radiator circuit. The calculated friction pressure loss through the main obtained by substituting 1 in. iron pipe for 3/4 in. copper tube in the trunk and using the observed flow rate of 5.8 Gpm is 20 ft of water. Since this is a greater friction pressure loss than that obtained by using the tube sizes and flow rates indicated in Table A, it is apparent that the pipe sizing procedures for the small pipe system were on the safe side. Furthermore, since the calculated friction head for actual conditions of operation exceeded the catalogued pump head by 6 ft of water, it seems probable that the allowance for fittings and orifices was more than actually required.

Table C shows the measured temperature drops in all parts of the heating system. With the exception of the drop through the dining room baseboard, all were less than the design value of 20 F which should be expected since the actual water flow rate exceeded the design value. There were two factors contributing to the high temperature drop through the dining room baseboard. In the first place the 3/8" tube used in the radiator circuit was slightly undersized. As shown in Table A the allowable friction head in this circuit was 745 milinches per foot while the friction head in a 3/8 in. tube carrying 0.87 Gpm is 762 milinches per foot. In addition to this the main circuit to which this unit was connected was slightly overloaded and furthermore the supply tee and orifice for the dining room baseboard were located just downstream of the supply tee for the S. W. bedroom baseboard. All of these tended to reduce the flow through the dining room baseboard. A high temperature drop through a room heating unit is not as serious as it appears since the mean radiator temperature is decreased only one half as much as the temperature drop is increased and the decrease in output of the heating unit is only about 0.9 percent per degree F. If it is assumed that changes in water flow

rate have a negligible effect on the output of a baseboard, the following equation is true.

$$\Delta T \times W = C$$

where

ΔT = Temperature drop through the baseboard

W = Water flow rate through the baseboard

C = a constant

The water flow rates through the individual baseboard circuits were not measured. Nevertheless it is true that the ratio of the water flow rate through the radiator circuit to the water flow rate through the main is a constant and therefore, by changing the value of C in the preceeding equation the water flow rate in the main may be substituted for the flow rate through the radiator. In this way it may be shown that reducing the water flow rate in the system from 5.8 Gpm to 4.5 Gpm would increase the average temperature drop through the heating units to about 20 F, the design value. This indicates that the sizing of the orifices in the supply tees and the method of sizing the piping for the radiator branch circuits was satisfactory.

When the system was first started, a few expansion and contraction noises in the piping system were observed. These were traced to pipe straps which were too tight to permit movement of the main. These were loosened and from that time on no noise in the piping system was observed, either as a result of expansion and contraction or from high water velocity.

No unusual venting problems were encountered even though there were places in the piping system where air could be trapped. The water velocity was apparently sufficient to carry the air along with the water until it reached either the boiler or the radiation where the water velocity was low enough to permit separation.

Summary

The use of small diameter, soft, copper tube for the construction of an experimental one-pipe hot-water system for the I=B=R Research Home resulted in a reduction of about $150.00 in the installation cost with no sacrifice in the overall performance of the system. The design procedures used proved to be on the conservative side and may be incorporated in the I=B=R Installation Guides without introducing an entirely new method of design. All that would be required is an expansion of the pipe sizing table and some comments on the installation techniques of installing the small diameter pipe efficiently.

Appendix A.

Revisions Required in Installation Guide 500 to Make It Adaptable To Small Pipe Systems

A revision of the pipe sizing table (Table 3) in I=B=R Installation Guide No. 500 is required to make this guide applicable to the design of small pipe systems. A suggested revision is shown in Table D. This table is applicable to copper tube only as the friction heads of copper tube and iron pipe are quite different for the same nominal size in the smaller diameters.

The carrying capacities of the radiator circuits in Table D are based on the use of an orifice as illustrated in Fig. 2, or other suitable device which will develop a pressure head in the radiator circuit equivalent to the friction head in approximately 12 ft. of the main to which the radiator circuit is joined.

Table E summarizes the pipe size selection for the system installed in the I=B=R Research Home using Table D and the procedure described on pages 23 through 25 of I=B=R Installation Guide No. 500. Comparing the pipe sizes shown in Table E with those in Table A it is found that the use of Table D and the simplified procedure resulted in the same pipe size selection as the more exact method of using the equivalent length of each circuit (Table A). The dining room riser size in Table E is 1/2 in. while in Table A it is only 3/8 in. However it should be noted that the 3/8 in. tube was actually undersized.

It is also suggested that some description of installation methods for small diameter soft copper tube should be included in the revisions as these procedures are not familiar to most contractors.

Appendix B

Method of developing pipe sizing table, Table D

Step 1. Select a unit friction head.
Example: Unit friction head taken as 600 milinches per ft. (this represents the third column in Table D)

Step 2. For each available head, determine the equivalent length of the circuit by dividing the available head in milinches by the unit friction head selected in step 1.
Example: Available head = 8 ft of water
Equivalent length = 8 x 12000/600 - 160 Ft.

Step 3. For each equivalent length, determine the measured length from table F. Round out measured length to nearest 10 ft. and record in upper portion of Table D under total length of circuit.
Example: 160/1.63 = 98 ft. Record 100 ft.

Step 4. For selected unit friction head (Step 1), determine the carrying capacity of main sizes from an accepted friction pressure loss chart. Record to nearest 0.1 Gpm opposite trunk or circuit in Table D
Example: Unit friction head = 600 milinches per ft.
Carrying capacity 3/4 in. type L copper tube = 4.0 Gpm.

Step 5. Multiply the selected unit friction head (step 1) by 15 to determine the available head to overcome friction in the branches.
Example: 600 x 15 = 9000 milinches

Step 6. Assume the equivalent length of the branch to be 30 ft. This was the average equivalent length of a branch circuit in the I=B=R Research Home.

Step 7. Divide the available head determined in Step 5 by the equivalent length of the branch (Step 6).
Example: 9000/30 = 300 milinches per ft.

Step 8. For each unit friction head in branch (Step 7) determine the carrying capacity of each branch size from accepted friction pressure loss charts. Record to nearest 0.1 Gpm in Table D.
Example: Unit friction head = 300 milinches per ft.
Carrying capacity 3/8 in type L copper tube = 0.5 Gpm.

Appendix C

Determination of Orifice Size

The size of the orifice required to increase the equivalent length of the main by 12 ft. may be determined by the following formula.

$$Q = KA\sqrt{2gh} \quad \text{or} \quad A = Q/K\sqrt{2gh}$$

where

Q = Flow rate in cu. ft. per sec.
A = Orifice area in sq. ft.
K = Orifice coefficient (assumed as 0.65)
g = Gravitational acceleration, ft. per sec^2 (32.2)
h = Head Loss through orifice in ft. of water

It is apparent that the area of the orifice is a function of the flow rate. However, the changes in flow rate normally encountered in any main of a given size in a conventional heating system are not large enough to have much effect on the orifice size.

Sample calculation:

Main size = 1/2 in.
Flow rate = 1.0 Gpm
Unit pressure loss in main = 330 milinches per ft.
(from friction pressure loss chart)

$h = 12 \times 330/12000 = 0.33$ ft. of water

$A = 1.0/450 \times 1/0.65 \times 1/\sqrt{64.4 \times 0.33} = 0.000738$ sq. ft. or 0.106 sq. in.

Diameter of orifice = $\sqrt{0.106/0.786} = 0.384$ in.

Using the above procedure and selecting flow rates corresponding to representative carrying capacities of the main the following orifice diameters were found to be required to increase the equivalent length of the main by approximately 12 ft.

Main size in.	Orifice diam in.
3/8	0.27
1/2	0.38 (13/32 or 0.41 in. was used in the installation in the I=B=R Research Home)
3/4	0.61

TABLE A.

PIPE SIZING SUMMARY

Section (Fig. 1)	Maximum Allowable Friction Head* Milinch/Ft	Flow Rate GPM	Nominal Tube Size	Water Velocity Ft/sec.	No. of Elbow Equivalents of Fittings	Elbow Equivalents in Ft. of Tube	Measured Length	Equivalent Length	Friction Head Milinch per Ft.	Friction Head Milinch in Section
Ja	966	4.32	3/4	3.0	20	40	7	47	750	35,350
dhi	966	4.32	3/4	3.0	4	8	19	27	750	20,250
abcd	966	2.13	1/2	3.0	10	15	37	52	1180	61,360
Supply Tees & Orifice	966	2.13		3.0		48		48	1180	56,640
Total						111	63	174		173,600 or 14.5 Ft of Water
N. W. Bed.	403	1.02	Sup. 1/2	1.5	9	9	27	36	360	
		.49	Ret. 3/8	1.2					277	
N. E. Bed.	403	.44	3/8	1.0	7	7	29	36	222	
Liv. Room	1035	.57	3/8	1.3	7	7	7	14	360	
Vest.	580	.48	3/8	1.2	7	7	18	25	277	
Lav.	414	.15	3/16**	0.9	7	7	28	35	305	
Ja + dhi	894	4.32	3/4	3.0	24	48	26	74	750	55,400
afed	894	2.19	1/2	3.1	10	15	39	54	1190	64,260
Supply Tees & Orifice	894					60		60	1190	71,400
Total						123	65	188		191,060 or 15.9 Ft of Water
S. W. Bed.	383	1.02	Sup. 1/2	1.5	9	9	26	35	360	
		.53	Ret. 3/8	1.3					360	
Din. Room	745	.87	3/8	1.9	7	7	11	18	762	
Bath	419	.26	1/4	1.1	7	7	25	32	346	
Kitch.	609	.31	1/4	1.3	7	7	15	22	485	
Stair.	335	.22	1/4	0.9	7	7	33	40	263	

** 1/4 in. Installed

* Available Pump Head = 14 Ft. of Water.

TABLE B.

ESTIMATED INSTALLATION COSTS - NEW CONSTRUCTION
Conventional Iron Pipe vs Small Diameter Copper Tube

	Conventional iron pipe system		Small diameter copper tube system	
Item	Quantity	Cost	Quantity	Cost
Pipe or Tube	341 Ft.	$47.90	323 Ft.	$64.26
Fittings	159	56.35	85	23.47
Labor $3.50 per hour	63 Hr.	220.50	24 Hr.*	84.00
Total		$324.75		$171.73

* = Estimated for new construction by installer of system in I=B=R Research Home

TABLE C.

WATER TEMPERATURE DROPS, SMALL PIPE SYSTEM

Location	Temp. Drop F	Location	Temp. Drop, F
Kitch. Rad.	18.3	Bath Rad.	13.5
Din. Baseboard	25.6	S.W.Bed.Basebd.	17.2
Liv. "	10.2	N.W. " "	14.3
Vest. Rad.	5.3	N.E. " "	12.0
Lav. "	17.6	Av. all heating units	15.0
Stair. "	15.8	Boiler	16.4*

* temperature rise

TABLE D

PIPE SIZING TABLE FOR ONE PIPE SYSTEM

Available Head in Ft. of Water	TOTAL LENGTH OF CIRCUIT (see note 1)																		
4	30	40	50	55	60	65	70	75	80	90	100	110	130	150	170	220	280	390	630
5	35	50	60	65	70	80	90	95	100	110	130	140	160	190	230	280	360	510	790
6	40	60	70	80	90	100	110	120	130	140	150	180	200	230	280	350	450	620	960
7	50	70	80	100	110	120	130	140	150	170	190	210	240	280	340	420	540	740	1120
8	55	80	100	110	130	140	150	160	180	190	220	250	280	330	400	490	620	850	1280
9	65	90	110	130	140	150	170	180	200	220	250	280	320	380	450	550	710	960	1440
10	70	100	120	140	160	180	190	210	230	250	280	320	370	430	510	620	790	1060	....
11	80	110	140	160	180	200	210	230	250	280	310	360	410	480	570	690	880	1180	....
12	85	120	150	180	200	220	230	250	280	310	350	390	450	520	620	760	960	1280	....
14	105	140	190	210	240	260	280	310	340	370	420	470	540	620	740	900	1120	....	....
Pipe Sizes	**GALLONS PER MINUTE CAPACITIES OF TRUNK OR CIRCUIT AND BRANCHES**																		
3/8" Trunk or Circuit	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.2
1/4" Branch	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	..
3/16" Branch	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	..	..	..	..	..	..	..
1/2" Trunk or Circuit	2.0	1.7	1.4	1.4	1.3	1.2	1.2	1.2	1.1	1.0	0.9	0.9	0.9	0.8	0.7	0.7	0.6	0.5	0.4
3/8" Branch	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1
1/4" Branch	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	..
3/16" Branch	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	..	..	..	..	..	..	..
3/4" Trunk or Circuit	5.2	4.6	4.0	3.7	3.5	3.4	3.2	3.1	3.0	2.8	2.6	2.5	2.3	2.2	2.0	1.8	1.6	1.3	1.1
1/2" Branch	1.8	1.6	1.4	1.3	1.2	1.2	1.1	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.4
3/8" Branch	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1
1/4" Branch	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	..
3/16" Branch	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	..	..	..	..	..	..	..

NOTE 1: Measured length of circuit (not including branch piping) plus an allowance of 12 feet for each heat distributing unit connected to circuit.

TABLE E.

PIPE SIZE SELECTION USING TABLE D.

Section (Fig. 1)	Flow Rate GPM	Measured Length, Ft.	Pipe Size (Table D)*
Ja + dhi	4.32	26	3/4
a b c d	2.13	37	1/2
Totals		63 + 48 = 111	
N. W. Bed.	1.02 Supply .45 Return		1/2 3/8
N. E. Bed.	.44		3/8
Liv.	.57		3/8
Vest.	.48		3/8
Lav.	.15		3/16
Ja + dhi	4.32	26	3/4
a f e d	2.19	39	1/2+
Totals		65 + 60 = 125	
S. W. Bed.	1.02 Supply .53 Return		1/2 3/8
Din.	.87		1/2
Bath.	.26		1/4
Kitch.	.31		1/4
Stair.	.22		1/4

* Available Pump Head = 14 Ft. of Water

TABLE F.

EQUIVALENT VS MEASURED LENGTH

Measured = (L) Lengths	Ratio of Equivalent Length / Measured Length = (R)	Equivalent Length
50	1.72	86
75	1.67	125
100	1.63	163
125	1.59	199
150	1.56	234
200	1.50	300
250	1.45	363
300	1.41	423
350	1.38	483
400	1.35	540
450	1.33	599
500	1.31	655
600	1.29	774
700	1.27	889
800	1.26	1008

Equivalent Length = (R)(L)

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
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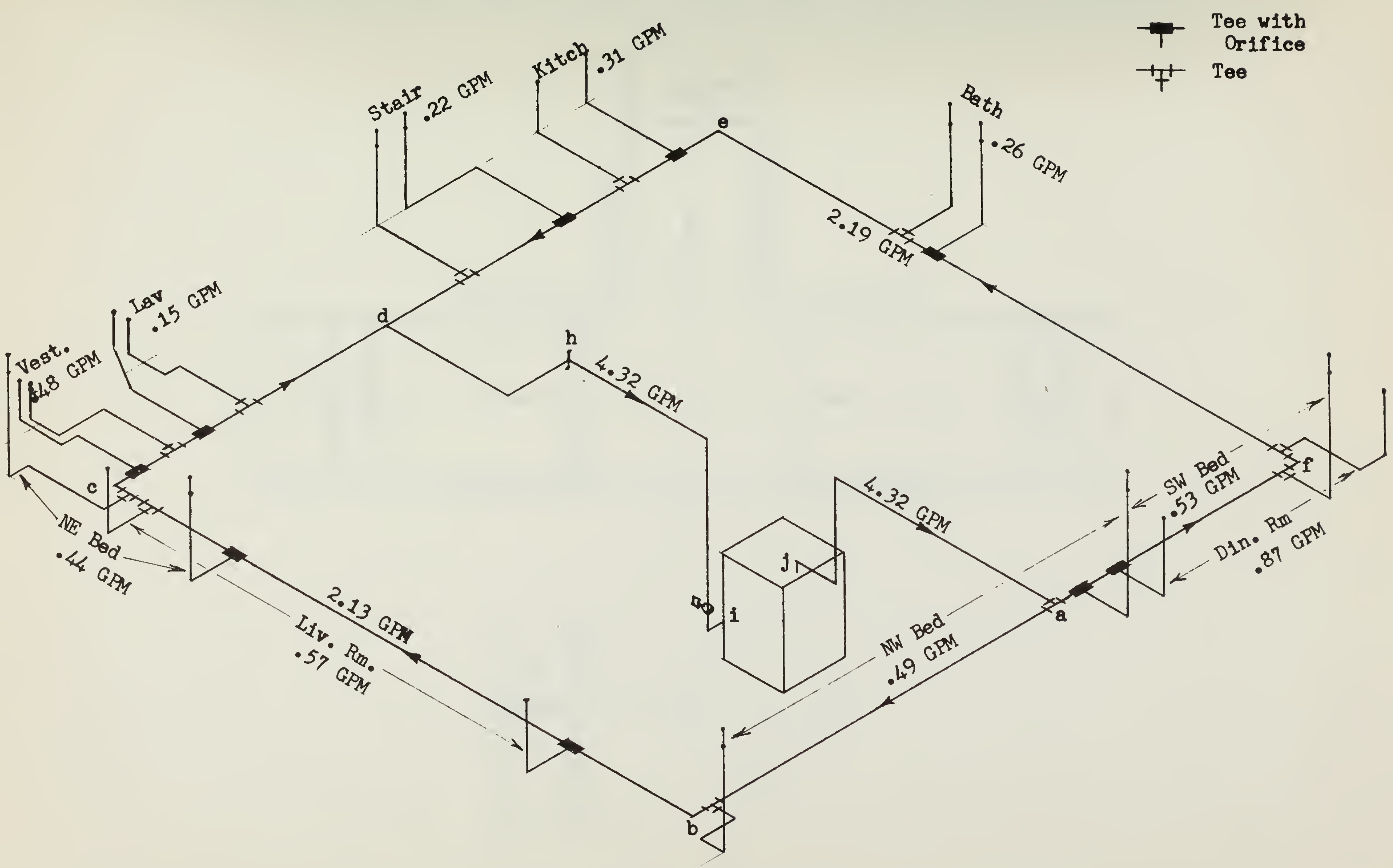

Fig. 1 SMALL PIPE HEATING SYSTEM 1958

DETAIL OF SUPPLY TEE — 1958-59 HEATING SYSTEM

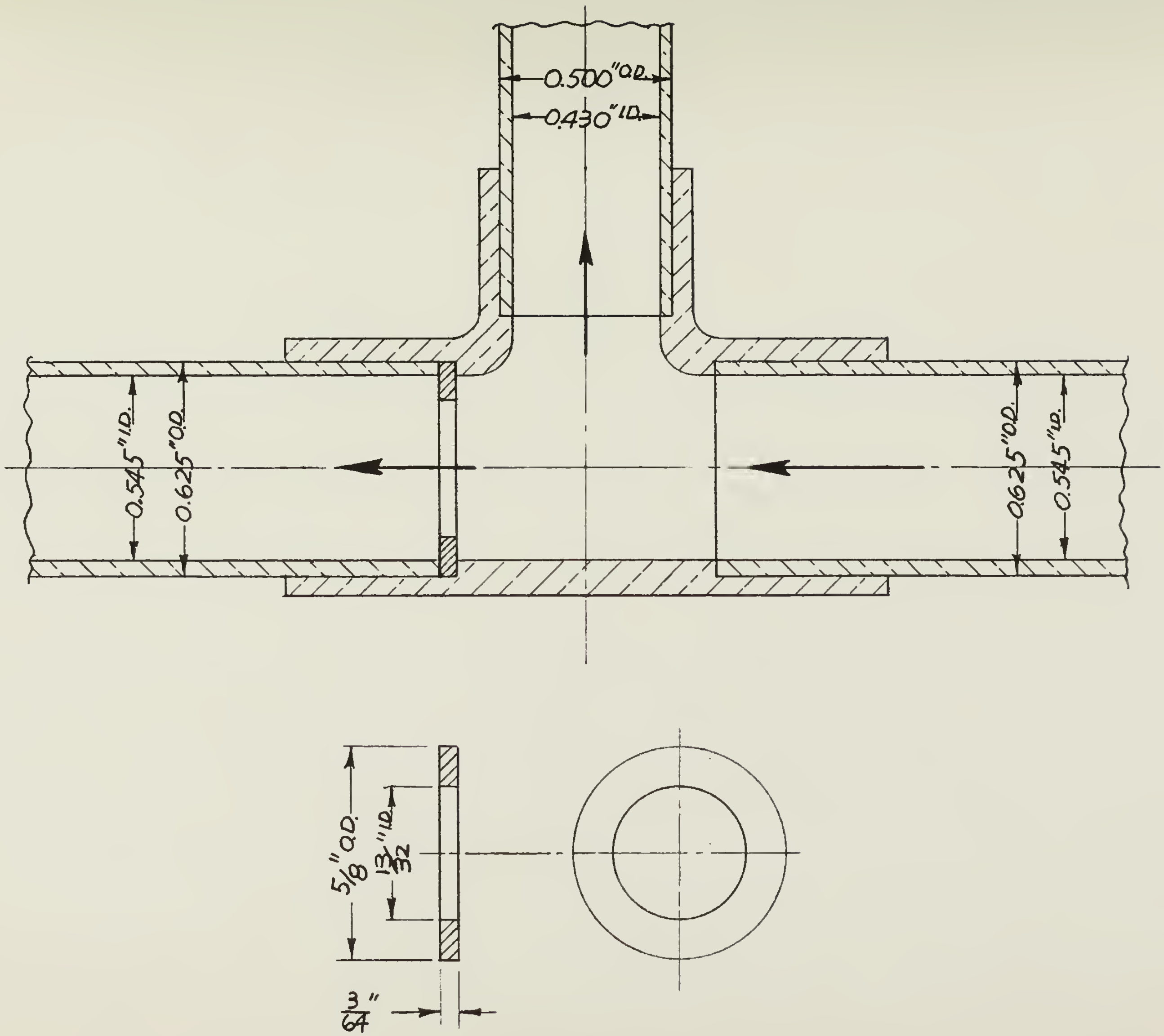

FIG. 2

9/10/58